

SAN ANTONIO SIGGRAPH #2002#

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Physiological Measures of Presence in Stressful Virtual Environments

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Outline



Heart rate assesses presence in stressful
virtual environments.

- Introduction
- Lets see it!
- Results
- Questions

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Presence

- Presence is defining factor for some VEs [Hodges, 1995].
- Many definitions - *being there* in a VE.
- Ours: *perceiving stimuli as one would perceive stimuli from a similar real environment.*
 - Example: Taking a tour of Louvre, listening to the tour guide.

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Desired Presence Measure

- Researchers have yearned for a measure that is
 - Reliable – repeatable results.
 - Valid – measures subjective presence.
 - Sensitive – distinguish multiple presence levels.
 - Objective – no subject or experimenter bias.
- Is physiological reaction such a measure?

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Presence in Stressful VEs

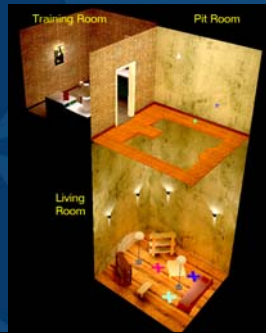
- We show for stressful VEs:
 - Feeling presence -> feeling stress.
 - More presence -> more stress reaction.
- Therefore, physiological reaction – measure in stressful VEs.

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Physiological Reaction

- **Looked for:**
 - Practical to measure and well studied.
- **Fear-of-falling stress.**
 - Heart rate ↑
 - Skin conductance ↑



Our VE - a Strong Stimulus

- **Compelling** [Usch, 1999].
 - Come see at ETech!
- **Why use the extreme?**
 - Physiological measures not work with so strong a stimulus, not work at all.



Video

Three Studies

Study	Multiple Exposures	Passive Haptics	Frame Rate
N	10	52	33
Exposures (conditions)	12x over 4 days (identical)	2x (Y/N ledge)	4x (10,15,20,30 FPS)



Measures

Results

- **Physiological Measures**
 - $\Delta \text{Heart Rate} = \text{Mean Heart Rate}^{\text{Pit}} - \text{Mean Heart Rate}^{\text{Training}}$
 - $\Delta \text{Skin Conductance} = \text{Mean Skin Cond}^{\text{Pit}} - \text{Mean Skin Cond}^{\text{Training}}$
- **Uni. College London Presence Quest.**
 - Reported Presence (7Qs)
 - Reported Behavioral Presence (3Qs)



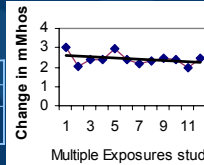
- **Our data supports $\Delta \text{Heart Rate}$**
 - Reliable, valid, sensitive, and objective measure of presence.
- **Some support for $\Delta \text{Skin Conductance}$.**
- **We show for a stressful VE:**
 - Feeling presence -> feeling stress.
 - More presence -> more stress reaction.
- **I will discuss primarily Heart Rate.**



Reliability: Reaction to Zero?

- **Mean reaction to Pit Room > Training Room:**
 - Both measures all studies ($P < 0.001$).
- **All measure decrease, all studies: physio. & reported.**
 - Significant decreases in at least one study.
- **Physiological reaction decreases but not to zero over 2-12 trials.**
- **There are reactions even after multiple trials = usable!**

	Reliable	Valid	Sensitive	Objective
Δ Heart Rate	✓			
Δ Skin Conductance	✓			



Validity: Correlations

- **Correlate with well-established UCL Presence Questionnaire?**
- **Δ Heart Rate:**
 - (+) correlations: all studies (no data Mult. Exp.).
 - Sig. + corr in Frame Rate w/ Rep Pres., Rep Behav. Pres.
- **Δ Skin Conductance:**
 - Mostly positive correlations, some significant
- **Follow conditions? (Up next)**

	Reliable	Valid	Sensitive	Objective
Δ Heart Rate	✓	✓		
Δ Skin Conductance	✓	✓ / X		

Sensitivity

- **Can the physiological measures**
 - Differentiate between Pit and Training Rooms?
 - Yes: Reported above in Reliability ($p < 0.001$)
 - Differentiate inclusion of 1.5" wooden ledge?
 - Differentiate frame rates?

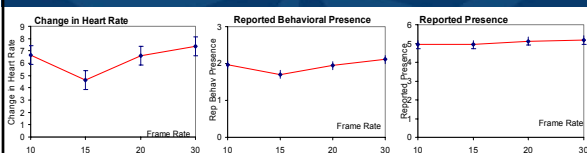
Sensitivity: Passive Haptics

- **Differentiate with & without 1.5" wooden ledge.**
 - Significantly higher with wooden ledge:
 - Δ Heart Rate (2.7 BPM, $P = 0.016$)
 - Δ Skin Conductance (0.75 mSiemens, $P = 0.040$)
 - Reported Behavioral Presence (0.47, $P = 0.004$)
 - Reported Presence (0.45, $P = 0.060$)



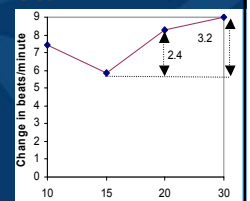
Sensitivity: Frame Rate

- **Anomalously high responses at 10 FPS:**
 - All physiological and behavioral.
 - Only Reported Presence not affected.
- **Not due to increased presence near 20' pit.**
- **Caused by fear of walking near a 20' drop w/ poor visual feedback.**
 - Discomfort, added lag, reduced temporal fidelity
- **Ostensibly dangerous: walking next to a 20' pit**



Sensitivity after 10 FPS

- **Δ Heart Rate most sensitive of measures**
 - 15 to 30 FPS: 3.2 BPM, $P = 0.004$
 - 15 to 20 FPS: 2.4 BPM, $P = 0.024$
- **Reported Behavioral Pres:**
 - Sign. increase 15 to 30 FPS:
 - 0.41 more "high" counts, $P < 0.008$



Sensitivity

- **Δ Heart Rate**
 - Support in Frame Rate and Passive Haptics
- **Δ Skin Conductance**
 - Mixed support for sensitivity.
- **Next: argue objectivity.**

	Reliable	Valid	Sensitive	Objective
Δ Heart Rate	✓	✓	✓	
Δ Skin Conductance	✓	✓ / X	✓ / X	

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Objectivity

- **Questionnaires:**
 - Experimenter bias.
 - Subject bias.
- **Physiological Reaction**
 - Not exposed to bias.
 - Subject - hard to modify and no biofeedback.
 - Experimenter - provided instructions are uniform.

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Conclusions

- **As measures of presence in stressful VEs:**
 - Δ Heart rate:
 - Reliable, valid, sensitive, objective.
 - Δ Skin conductance:
 - Reliable, ~valid, ~sensitive, objective.

	Reliable	Valid	Sensitive	Objective
Δ Heart Rate	✓	✓	✓	✓
Δ Skin Conductance	✓	✓ / X	✓ / X	✓

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Acknowledgments

- My family, Anuja Antony.
- Drs. McMurray, Lastra, Girdler, Bishop.
- UNC Effective Virtual Environment group: Razzaque, Harris, Kohn, McLaurin, Zimmons.
- Betsy Ray, Winnona Poulton.
- Drs. Mendozzi & Puginetti (Milan).
- NIH National Center for Research Resources Grant Number P41 RR 02170.
- UNC-CH Dissertation Completion Fellowship.

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Have You Looked over the Edge?

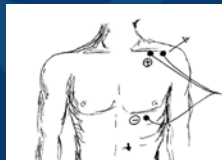
- Your heart races?
- Your hands get
- cold and clammy?





Measuring Physiological Reaction

- **Heart rate: Beats / minute (BPM):**
 - Blood Volume Pulse Photoplethysmograph - not a clean signal (Multiple Exposure).
 - Electrocardiograph - used in Passive Haptics and Frame Rate.



Measuring Physiological Reaction

- **Skin conductance (mMho):**
 - Amount of sweat on palms of hand.
 - Two electrodes on left hand.
- **Skin temperature - degrees Fahrenheit (oF):**
 - Thermistor taped onto left middle finger.



Analysis

- **Investigated reliability, validity, sensitivity, and objectivity of physiological measures.**
 - **Reliability:**
 - Consistent reaction to Pit Room?
 - Does reaction drop to zero over limited # exposures?
 - Does not in real environments [Abelson, 1989].
 - **Validity:**
 - Correlate with well-established presence questionnaire?
 - Consistently follow hypotheses?
 - = More Valid [Singleton, 1993].

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Analysis

- **Sensitivity:**
 - Difference between Training Room & Pit Room?
 - Differences in condition: 1.5" wooden ledge, frame rates?
- **Objectivity:**
 - Argued logically.

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Statistics

- **5% = statistical significance ($P = 0.050$).**
- **Sensitivity:**
 - SPSS 10.0.1 Univariate General Linear Model.
 - Using Repeated Measures technique described in [SAS, 1990].
- **Difference in means:**
 - T-test.
- **Correlations:**
 - Bivariate Pearson Correlation.
- **"P" = probability.**

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Future Work: Presence and VEs

- **Given compelling VE and good presence measure:**
 - What makes a VE compelling?
 - What were the combinations of minimum system characteristics to achieve this?
 - Aural localization,
 - Visual Detail,
 - Self-avatar fidelity,
 - Realistic physics in interactions with objects.

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Future Work: Physiological Presence

- **VEs that evoke different reactions:**
 - To use: feeling presence in the VE must evoke a physiological reaction distinct from laboratory environment.
 - We did this with danger-of-falling stress.
 - Possible with other stress.
 - Relaxation.
- **Compare real and virtual.**

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Future Work: Physiological Presence

- **Exposure to stressor for less time:**
 - Lag of 2-3 secs from stimulus (exposure to stressor) to reaction.
 - Heart rate is affected by respiration. Average over 2 cycles (1 cycle = 4 secs)
 - Skin temperature does not work well for exposures of less than 2 minutes.

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